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ABSTRACT

An instructional framework which provides opportunities for students to synthesize knowledge and recognize general approaches to problem representation and solution is advocated and discussed in this paper. The need for a combination of an interdisciplinary approach with the new technclogies of the information age is emphasized. Major ideas addressed include: (1) the need for knowledge integration; (2) the nature of complex systems, using the cardiovascular system as an example; (3) hierarchial representation of complex systems; (4) problem solving in complex systems, using the cardiovascular system as an example; (5) the role of the computer in teaching about complexity; (6) a way to modify the existing curriculum and to teach integrative thinking by using new computer-based simulations; and (7) a new professional activity, knowledge interface design, which will facilitate the transformation of the present curriculum. (ML)

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A Pedagogical Challenge: Integrative Thinking

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ABSTRACT

Undergraduate science curricula teach facts and concepts, developing skills of memorization and reductive analysis. These intellectual tools do not serve students well when they are faced later in their professional careers with applying their knowledge to solving problems in complex systems. Two activities, the diagnosis of problems and design of solutions, are common to all professions, yet students are not trained in these skills. The challenge is to implement a teaching methodology that develops in students an intellectual framework in which to embed what they learn, so that their use of knowledge is facilitated. Such a framework allows synthesis of knowledge and recognizes general approaches to problem representation and solution. This paper describes: (1) the need for knowledge integration; (2) the nature of complex systems, using the cardiovascular system as an example; (3) hierarchical representation of complex systems; (4) problem solving in complex systems, again using the cardiovascular system as an example; (5) the role of the computer in teaching about complexity; (6) a way to modify the existing curriculum to teach integrative thinking by using new computer-based simulations; and (7) a new professional activity, knowledge interface design, which will facilitate transforming the present curriculum.

THE NEED FOR KNOWLEDGE INTEGRATION

Our experience is with teaching physiology to students entering medical science professional schools (medicine and veterinary medicine). For the most part these students have already received a

bachelor's degree in one of the biological sciences. They come from reputable universities and have earned grades which rank them near the top of their class. They are capable and highly motivated learners. A case can be made that they are some of the best products of university undergraduate education.

Obviously, a principal goal in teaching physiology to medical and veterinary students is to teach it in such a way that they find it useful later in their professional lives. But the means to this goal is not clear to either teacher or student. The instructor knows which elements of knowledge should be taught, but lacks a structured means for integrating this knowledge and relating it to the kinds of problems students will encounter. The students are well experienced in acquiring knowledge, but they lack experience in synthesizing knowledge so that it serves a useful end. They also lack the necessary intellectual tools for performing such a synthesis. The students' previous educational experiences not only omitted synthetic exercises, but also taught the student to think in ways that are antithetical to synthetic thought.

The traditional teaching of science emphasizes facts and concepts and develops skills of memorization and reductive analysis. These skills focus on specifics. Generalities which unite these specifics are given in scientific terms only; these general views are not presented as a way to use knowledge synthetically. For example, the student is repeatedly led with analytical examples from the general to the specific; the ultimate explanation of biologic events is given in terms of specific molecular mechanisms. Such a focus does not serve the student well when faced with using knowledge in practical ways, such as

arriving at a diagnosis or designing a therapy, for it is integration which makes knowledge useful, and integration of the factual knowledge is lacking.

Faced with a nonscientific application of knowledge, the students are at loose ends to find any relevance in their science education. This, in spite of the fact that much of what is learned in science is of great applicability and can, within the proper intellectual framework, be of value in everyday life. The means for synthesizing knowledge into practical frameworks and the generalities that would make scientific knowledge useful in non-scientific settings are missing from the undergraduate curriculum. A different set of intellectual tools from those currently being fostered is required in order to achieve knowledge integration and, hence, practical application of knowledge.

UNDERSTANDING COMPLEX SYSTEMS

We feel that knowledge synthesis for practical purposes can be taught with the intellectual tools that have been developed for understanding complex systems. Theoretical procedures for aggregation, system reduction, decomposition, decision making, and problem solving have been emerging parallel to developments in computers. These procedures can be implemented in science education.

New learning environments are necessary--and possible. Our experience in the creation and use of new computer-based educational tools allows us to claim that tools can be developed to give students explicit demonstrations of integrative thinking and practice in using integrated thinking to solve problems. To foster the development and use of these tools in undergraduate education, we call for the training

of a new group of knowledge professionals. These professionals, drawn from a variety of backgrounds, will work with the traditional knowledge experts of various disciplines. Together they will embed traditional knowledge in the newer frameworks, making the organization of complex systems teachable and usable.

Franklin W. Wallin, president of Earlham College in Richmond, Indiana, writing in *Change*, March 1983, says the role of universities must be re-examined: "We will have to take a new look at an academic community that awards its highest accolades to those who make the narrowest slices of knowledge. We will need to find ways of connecting the disciplines and ways of assisting students and faculty in conceptualizing new patterns of knowledge." The teaching of integrative ways of thinking is one step toward preparing the students for bringing together knowledge from the different disciplines.

Our task in teaching physiology to medical professionals is not unique. The same intellectual tools are needed by engineers, urban planners, economists, and all other professionals. All science and social science disciplines are united by the goal of understanding and teaching about systems, processes, and interactions. To some degree ideas about complex systems are taught in present courses; however, these ideas are not taught with the aim of demonstrating their utility in designing, controlling, or debugging complex phenomena. We are certain that the same shortcomings we find in the preparation of our students are present in training students of other professions.

Concern over the quality of our educational system has been particularly topical since the April 1983 report by the National Commission on Excellence in Education, *A Nation at Risk: The Imperative*

for Reform. The object of reform should be the creation of a "learning society." If the zeal for reform is directed toward narrow, nationalistic goals, we will be no better off. Education can best serve national interests by placing emphasis on the cultivation of higher thought processes rather than the achievment of advantage over another country. Integrative thinking is one of those higher thought processes.

A recent National Institute of Education study group has recommended that "All bachelor's degree recipients should have at least two full years of liberal education. In most professional fields, this will require extending undergraduate programs beyond the usual four years." In the May 22, 1985, *Chronicle of Higher Education*, Frank H.T. Rhodes, president of Cornell University, calls the goal praiseworthy but naively unrealistic. Not more years but better spent ones are needed to achieve a liberal education, which Rhodes defines in terms of six skills. A college graduate should:

1. Be able to read and listen with comprehension and to write and speak with clarity, precision, and grace.
2. Have a sense of the context--physical, biological, social, historical--within which we live our lives.
3. Have some insight into a time and culture other than our own.
4. Be able to reflect in an orderly way on the human condition and our beliefs, values, and experience.
5. Be able to appreciate non-verbal symbols, including the creative and performing arts.

6. Be able to work with precision, rigor, and understanding in a chosen discipline, so as to understand no only something of its content but also its premises, relationships, limitations, and significance.

We would add a seventh: "A college graduate should be able to integrate knowledge about the parts of a complex system, so that actions taken on that system lead to a desired result."

Complex systems are the problem domain of all professional activities. Our world is characterized by global interdependence. The ability to understand complex interactions is a necessary intellectual tool. To be liberally educated, the student must have both a factual grasp of the multidisciplinary issues and the intellectual ability to create from those facts a decision-making strategy.

COMPLEX SYSTEMS: DEFINITION

A system is complex "when, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties (or behavior) of the whole" (Herbert Simon, *The Sciences of the Artificial*). Complexity arises when any of the following are present to a significant degree: 1) the properties of the parts are not constant, 2) there are numerous parts, 3) there are multiple interactions between parts, or 4) the interactions between parts takes on a circularly causal character. Inferences about behavior when these features are present are difficult because numerous things have to be considered at once. The limitation of the human mind to hold only seven items simultaneously in short-term memory makes it impossible to reason when more than this number of items must be kept in mind at the same

time. Intellectual techniques for working with complexity are those that allow a problem in a complex system to be solved by considering only a few things at a time, in a serial fashion.

COMPLEXITY AND HIERARCHICAL REPRESENTATION

Man has a natural inclination for representing complex systems in hierarchic form. This is such a strong characteristic that Simon has stated, "if there are important systems in the world that are complex without being hierarchic, they may to a large extent escape our observation and our understanding." Faced with the complexities that arise from multiple components and multiple interactions, we need to establish a means for appropriate hierarchic representation. Hierarchies are formed by using a simple representation to stand for multiple elements. Thus, organism encompasses multiple organs, organ encompasses multiple tissues, tissue encompasses multiple cells, cell encompasses multiple sub-cellular structures, etc. Parallel to the structural hierarchy is a functional hierarchy. Higher-level statements of function are a synoptic statement of lower-level functions plus emergent properties not found at the lower level. These emergent properties result from the interaction of the lower-level components. A hierarchy of process is created by collapsing multiple behaviors at lower levels into a simple, i.e., reduced, representation that approximates the net result. Thus, a simple global model of a subsystem is formed that captures in a few elements those features most important to overall function. The process of forming simple functional models may be repeated at successively higher levels in the hierarchy until a global model for the whole system is formed. The global model of the

whole system is the top member of the hierarchy. Lower members of the hierarchy are the models of the various system components. Model hierarchies are formed and abstractions are made by aggregating system elements into larger units. Aggregation is a means of synthesizing many details into a simple whole. Formal mechanisms of aggregation or model reduction are widely used in engineering in control systems and to facilitate the process of design. Less formal mechanisms of aggregation are used in management and business decision-making practices; simplified models of complex organizational systems are considered vital to the decision-making process and are purposefully sought. In physiology, aggregation is practiced more on an unstated intuitive basis than on an explicit formal basis, and when aggregation is done, the reasons for doing it are not well incorporated into the method and purpose of the science.

AGGREGATION: AN EXAMPLE FROM PHYSIOLOGY

We are using a package called Cardiovascular Systems and Dynamics (CVSAD) to teach integrative aspects of the cardiovascular system. CVSAD is itself an integrated package. It integrates models by allowing several isolated and independently functioning models of cardiovascular components to be assembled into interacting units and finally into an entire system. It is integrated software because it allows data to be shared among the many parts of the program so that when the model is assembled or decomposed, comparisons can be made between model behavior at all levels of the model hierarchy. Last, it teaches integrative thought by making explicit to the student a hierarchical format in which to think about this complex system. It provides the student with a

vision of the system that we feel is most appropriate for solving problems. CVSAD is the type of tool that we envision would be used in science courses to prepare students to use their knowledge in problem solving.

The way in which CVSAD is used to teach an integrative view of the cardioavascular system may be best illustrated by a brief tour through the laboratories:

The isolated left ventricle is the lowest level of the cardiovascular hierarchy which is available in the CVSAD program. Two concepts in that laboratory concern us here: 1) the response of the heart, in terms of ability to pump, to the pressure which primes or fills it: and 2) the response of the heart to the pressure into which it must pump (afterload or hydraulic load). Figure 1 shows that increased priming results in increased performance. Figure 2 shows that increased afterload results in decreased pumping performance.

A similar set of studies can be performed on the right ventricle with qualitatively the same results: increased priming increases performance while increased load decreases it. When the right and left ventricles are considered coupled together through the pulmonary circulation, a new aggregate unit is formed, the heart-lung blood pump. The interactions in this aggregate unit lead to a new function in the combined system. Figure 3 describes the same priming experiment as before, now performed on the heart-lung blood pump. The results are contrasted with those of the left ventricle alone; marked differences are seen. These differences constitute an important lesson--the functionality of the aggregate unit is different (in this case greater) than that of the isolated component. Figure 4 presents the result for

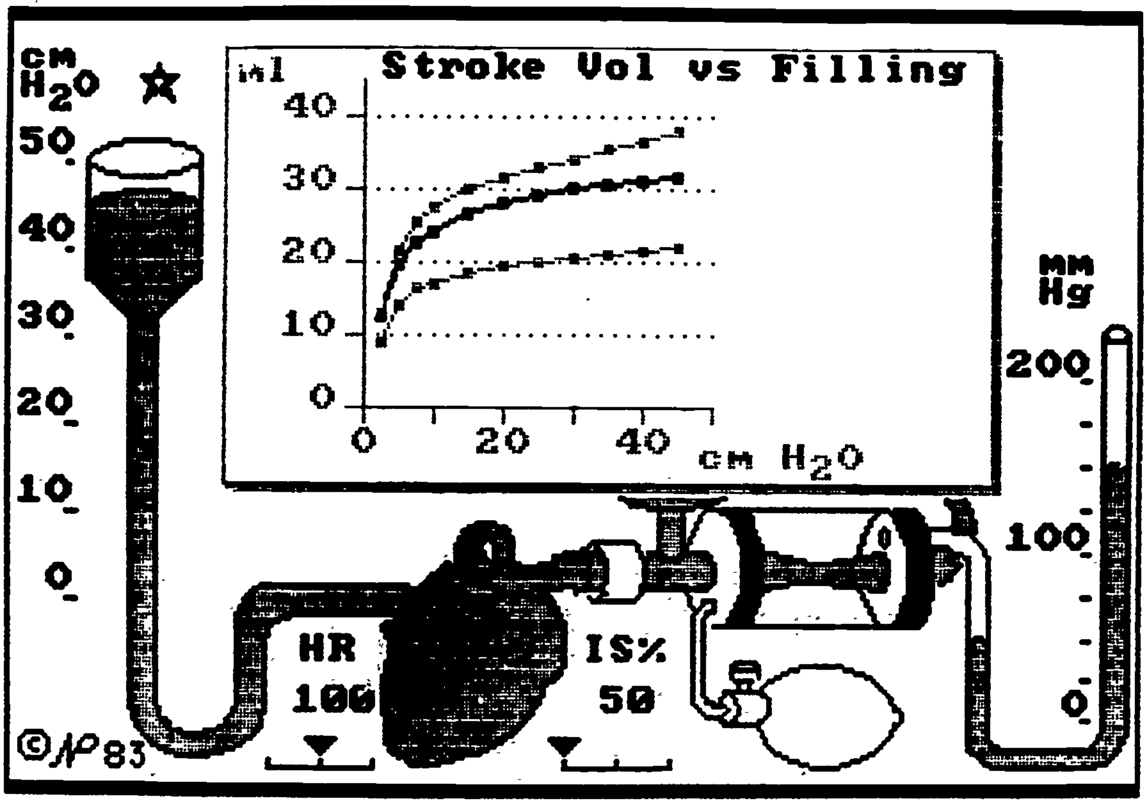

Figure 1. Computed results demonstrating Frank-Starling mechanism with preload experiments that are reminiscent of those done by Patterson and Starling. Stroke volume dependence on filling pressure for 3 contractile states. Curves connecting data points are (from top to bottom) 50% elevation in heart strength, normal strength, and 50% depression in heart strength.

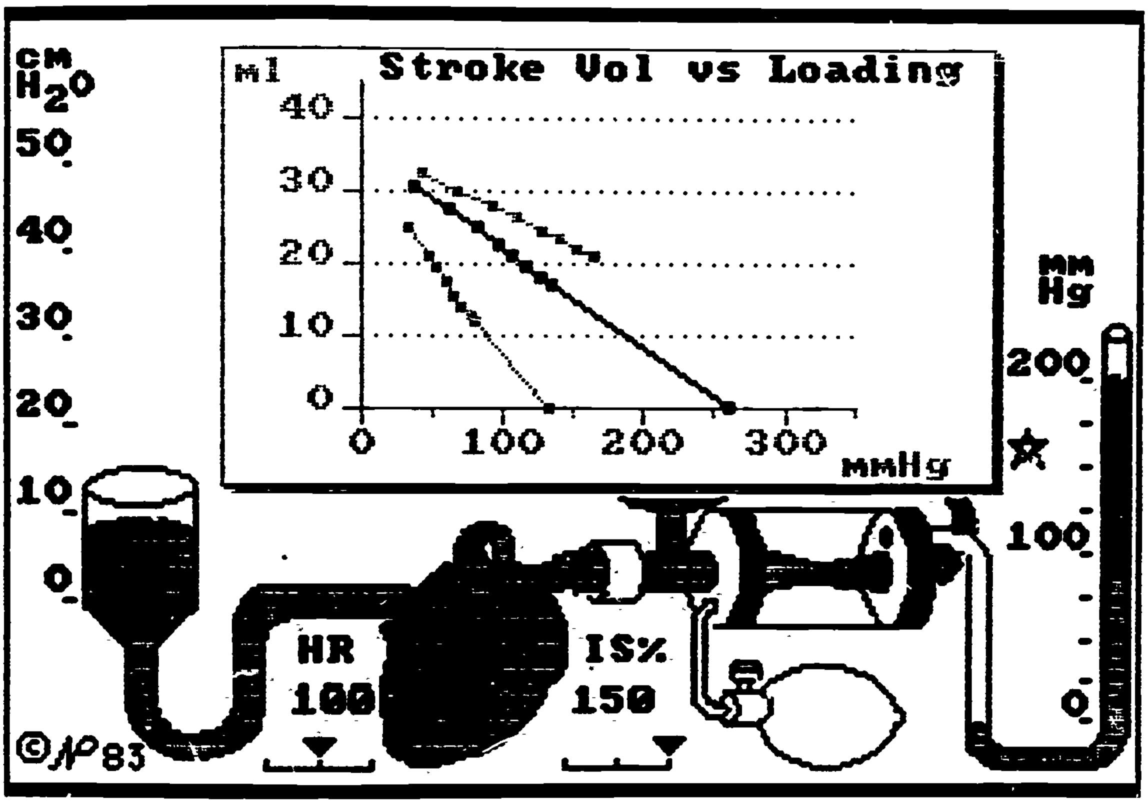

Figure 2. Variations in stroke volume as a function of afterload at 3 contractile states. Lines connecting data points are (from top to bottom) 50% elevation in heart strength, normal strength, and 50% depresssion in strength.

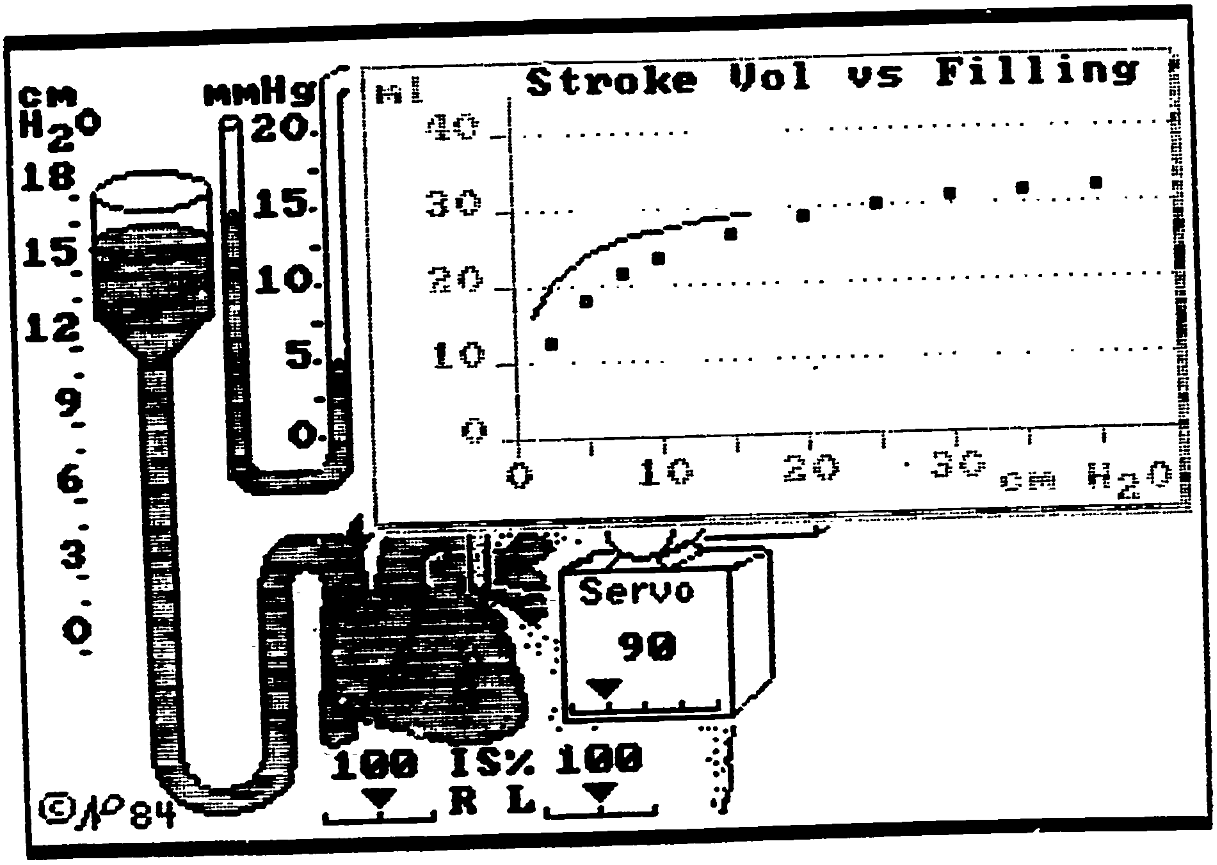

Figure 3. Results of two preload experiments: isolated left ventricle model (open boxes) and heart-lung model (solid line). The heart-lung blood pump is more sensitive to preloading changes; its curve is above and to the left of the isolated left ventricle curve.

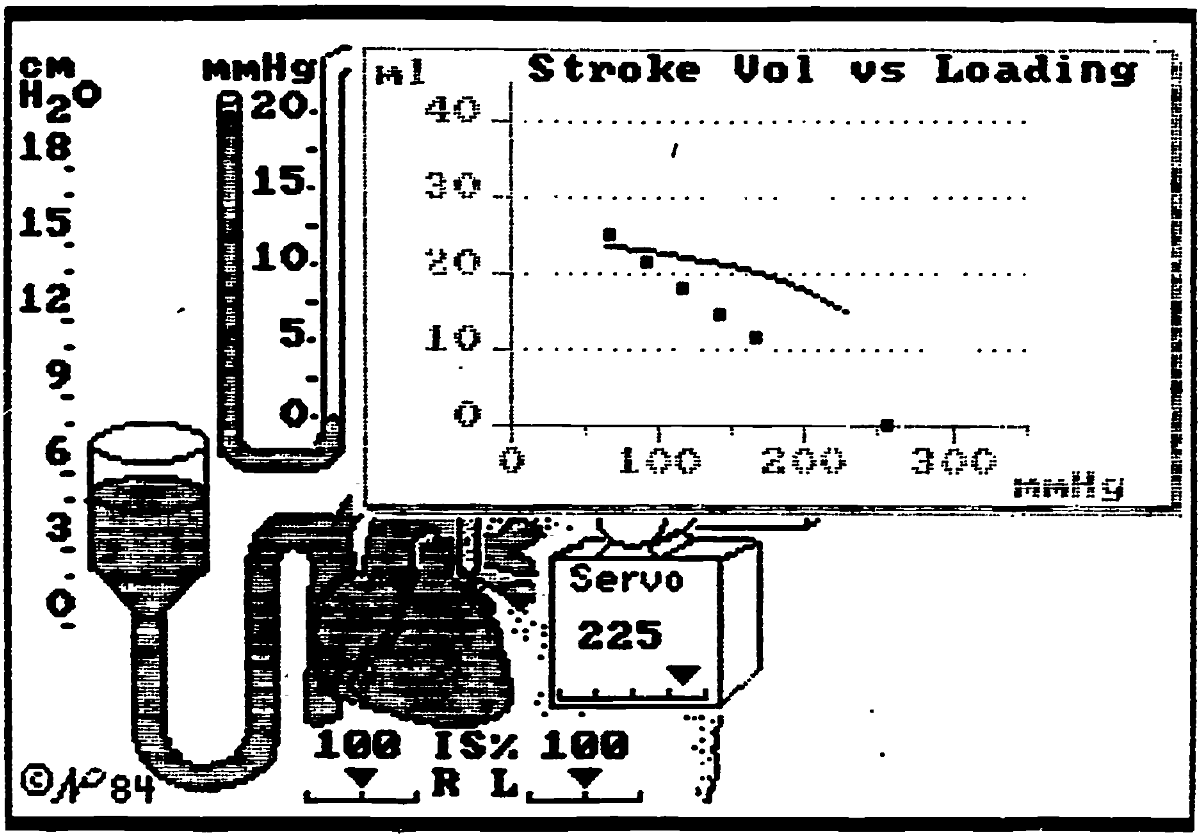

Figure 4. Results of two afterload experiments: isolated left ventricle model (open boxes) and heart-lung model (solid line). The heart-lung blood pump is less sensitive to changes in the afterloading variable; its curve is above and to the right of the isolated heart curve.

the afterload experiment. In this case the combined system is less sensitive (flatter slope) than the isolated ventricle. A major conclusion is that the quantitative function of the system changed as a result of interactions between components. While conducting the experiments in the heart-lung blood pump, the student can observe the mechanism through which these behavioral differences emerge. The mechanism, working through pressure, couples the right and left hearts in the pulmonary circulation. This pressure loads the right heart and primes the left heart in such a way that the aggregate heart-lung blood pump responds vigorously to pressure that primes the right heart but hardly at all to pressure that loads the left heart. Such behavior is important if adequate amounts of blood are to be pumped in the face of changing arterial and venous pressure environments.

In figure 5 we see another part of the cardiovascular system story. In this lab--the systemic circulation--a mechanical pump replaces the heart-lung pump. The laboratory permits experimentation with the arteries, capillaries and veins. Two related ideas are represented in the graphs of figure 5. Increased pumping increases the pressure in the arteries (graph on right). Simultaneously, increased pumping decreases the pressure in the veins (graph on left). In other words, as the mechanical pump works faster, blood is transfered from the veins to the arteries. Faster pumping serves to reduce the pressure priming the pump and to raise the load into which the pump must empty.

The effects observed in the heart-lung and the systemic circulation labs are opposite: increased pumping is caused by increased priming pressure (heart), and at the same time, increased pumping reduces the amount of blood available (lowers the pressure) to prime the pump

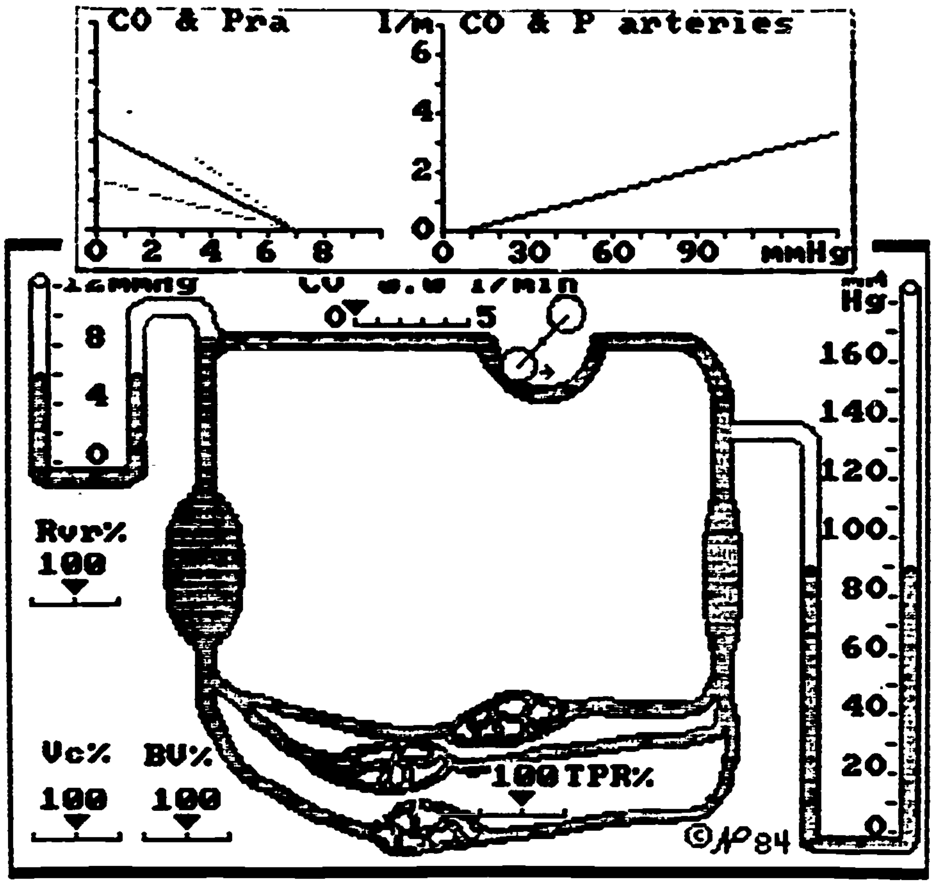

Figure 5. Results of varying mechanical pump speed in a systemic circulation laboratory. Left inset: venous pressure response to circulation velocity (equivalent to cardiac output). Right inset: arterial pressure response to circulation velocity.

(veins). Figure 6 shows the interaction of these opposite tendencies; the only place where all the requirements of system operation can be satisfied is at the two intersections of the four curves. In other words, the cardiovascular system can be conceived of as functioning at the points which describe the solution of two pairs of equations. This is a description which we find useful in assigning functional meaning to the operations of the cardiovascular system, not one which is intrinsic to the system itself.

In working with the program, students are guided to make the discoveries presented in figures 1 through 5 and to see them as a set of descriptions which are hierarchically arranged. We want them to develop a working model of the cardioavascular system like that shown in figure 6. This vision is a useful mental model when solving diagnostic problems.

SOLVING PROBLEMS IN COMPLEX SYSTEMS

Solving problems in complex physiological systems is a two-part process: 1) identifying a fault or an abnormality within the system (diagnosis) and 2) modifying system properties in order to achieve some goal in system behavior (therapy). In this paper we are concerned only with fault identification, but the intellectual tools for modifying system properties are the same.

An abnormality or fault in a single system component presents itself to the problem solver as some derangement in global system function. An understanding of detailed behavior of system components is usually not available through casual inspection. Therefore, problem solving relies on a directed search through the system, employing specialized

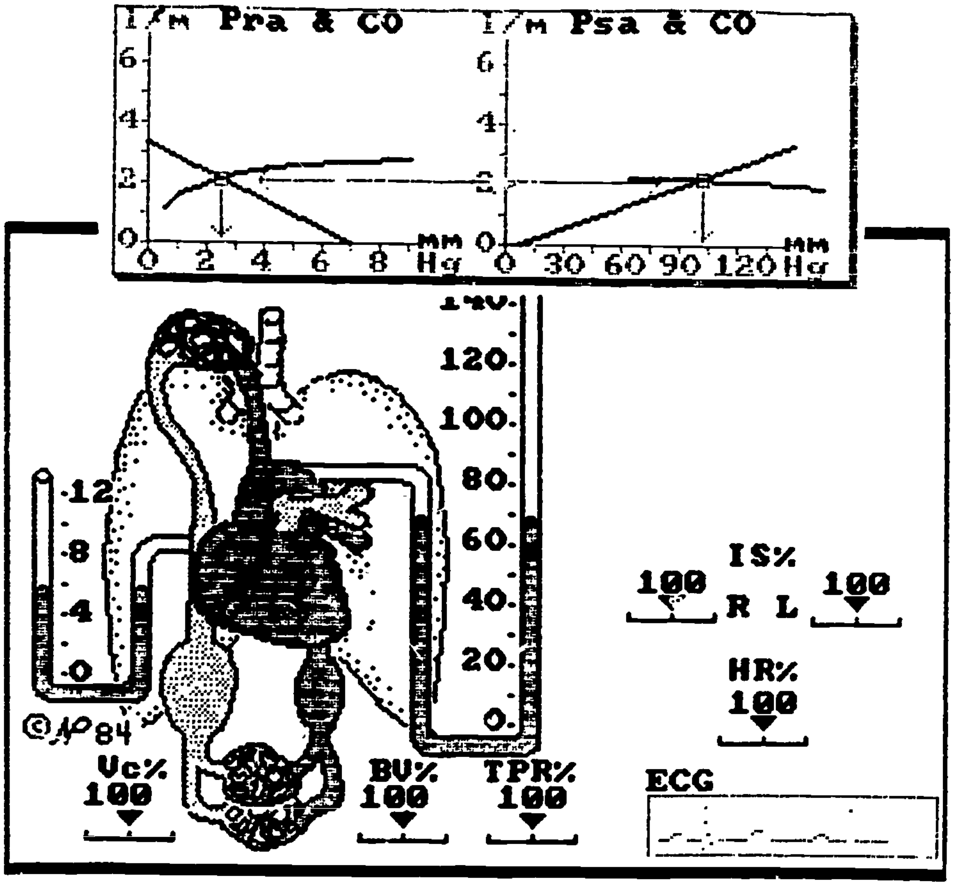

Figure 6. The complete cardiovascular system laboratory. Right inset: equilibrium condition for left heart-artery interaction, box. The line with positive slope was imported from figure 5, the other line from figure 4. Left inset: equilibrium condition for vein-right heart interaction, box. The line with negative slope was imported from figure 5, the other curve from figure 3. Only data represented by the two boxes may be displayed from the calculations in this laboratory. The lines, representing behavior of isolated components, must be created in their respective laboratories and imported. Conservation of volume requires the cardiac output indicated by these equilibria to be the same.

measurement procedures. In an idealized strategy, the search will follow a top-down path from the highest level, i.e., its global appearance, to the lowest level, i.e., the appearance of the part. Top-down thinking follows the same path that was developed in the preceding section for representing system complexity, but it goes in the opposite direction. A bottom-up approach was used before to analyze complexity: descriptions of parts and the basic laws of their interactions were synthesized into a description of global properties and behavior. However, the problem-solving task is top-down: it starts with an observed derangement in the behavior of the entire system followed by a need to identify the properties of a specific part. Because of this difference, the intellectual methods for solving problems in complex systems will necessarily be different from those that explain system behavior beginning with its elemental features.

Top-down decision making is based on the use of a hierarchical set of models of the system. These simple models require that only a few system features and interactions be considered at one time. At the highest level in the hierarchy there will be an abstract system model. It will have a reduced complexity that recognizes only general system functions. The lowest level of the hierarchy will be multiple detailed models of specific physical form and behavior, one for each individual system component. At intermediate levels will be models of progressively greater degrees of abstraction organizing progressively larger assemblages of components. Use of the models is made by searching through the hierarchy. Making decisions at any level arises from a consideration of the behavior of the relevant model.

Specifically, the challenge for teaching problem solving in complex systems is to develop in the student the intellectual ability to: 1) account for multiple items and issues and their interactions; 2) provide for emergent (higher-level) representation of lower-order processes; 3) order information hierarchically about a subject or problem; 4) take a top-down approach in problem solving; 5) choose between alternative designs and problem representations; and 6) communicate solutions coherently to others.

PROBLEM SOLVING: AN EXAMPLE FROM PHYSIOLOGY

CVSAD presents an explicit means for teaching the hierarchical organization of a complex system. An implicit method for teaching the same ideas is a problem-solving, or fault-finding, task. Both methods are useful, but a problem-solving task without some overall understanding of the system is insufficient. Two approaches may be taken to problem solving in a complex system: 1) serial reasoning from cause to effect, or 2) problem decomposition which recognizes and exploits the hierarchical nature of the problem environment. While each method may work for some problems, the serial reasoning approach fails in cases where the circularity of the problem causes feedback on the original cause to a significant degree. Because many complex systems have this feedback property we focus on teaching a hierarchical approach to problem reasoning. In figure 7 suppose that there is a fault in the resistance that separates the arteries and veins (point A). Two types of questions might be asked about this situation: 1) if the location and nature of the fault were hidden, one could ask that its location and magnitude be revealed, or 2) as a test of systems reasoning one could

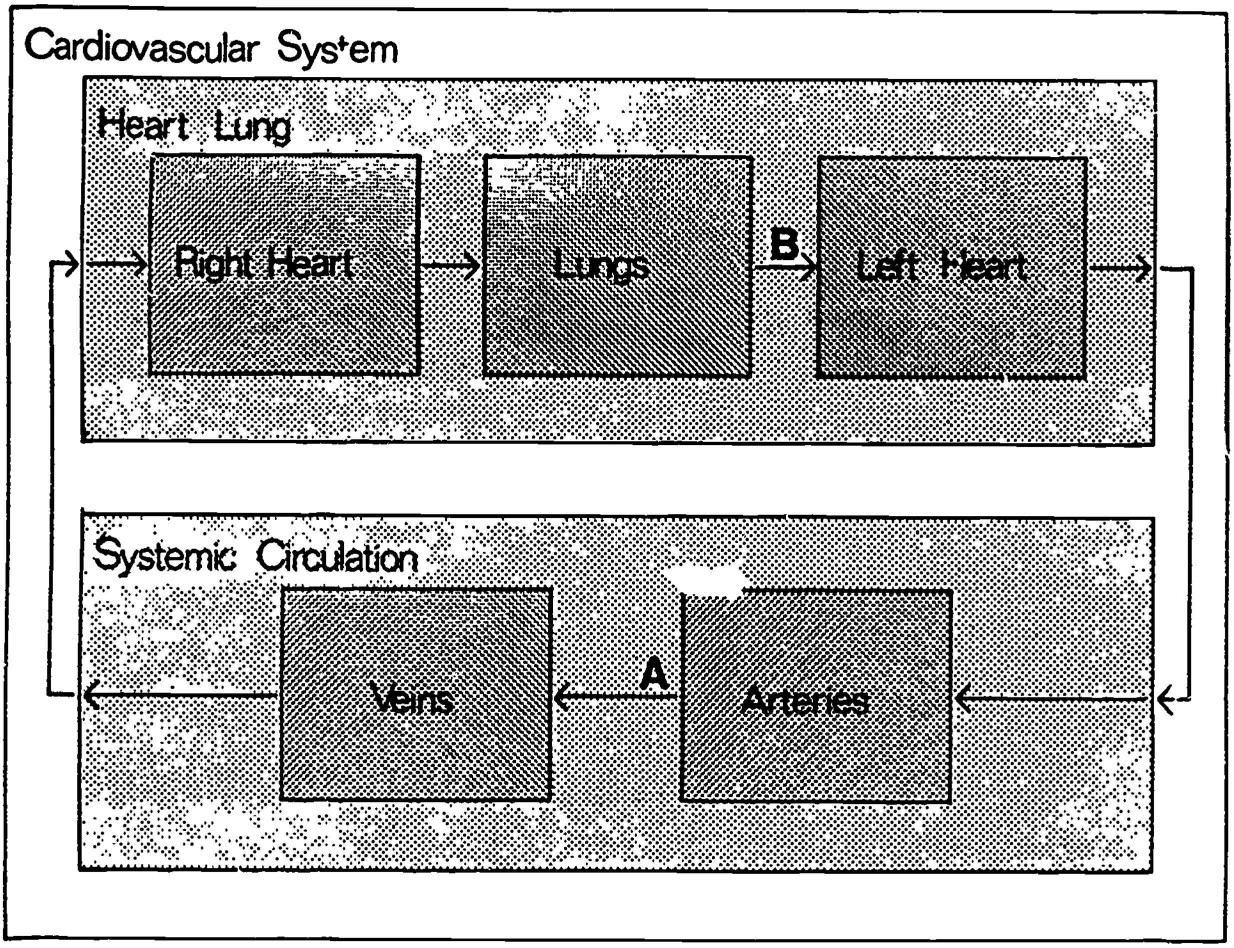

Figure 7. A functional boxes-within-boxes view of the cardiovascular system. The operation of the whole system depends on circular feedback around the loop. If a fault is introduced at point A (capillary resistance), its effect on the pressure at point B is difficult to predict by reasoning around the loop. A hierarchical decomposition makes prediction of the pressure at B feasible. See text.

also ask, as a consequence of a known fault at A, what will the pressure change be at point B (input to left heart)? Either question can be answered by reversing the hierarchical reasoning presented previously, but let's examine the second question: What is the nature of the pressure change at B given an increase in the resistance at A?

From an overall system viewpoint, an increase in resistance will dam up blood flow in the arteries. This damming up is another way of saying that blood will be redistributed from the veins to the arteries (behind the dam). Consequently, pressures in the arteries rise and pressures in the veins fall. We can divide the system and consider only the heart-lung blood pump component; pressures in the veins and arteries are assumed to remain fixed. An observation we made above in our experimentation with the heart-lung blood pump was that the pressure priming the left heart tended to rise with increases in the hydraulic load. Using our presumption of volume shifting from veins to arteries and consequent elevation of arterial pressure, we may now also conclude pump output will fall, and the pressure at point B must rise. When we presented students with similar fault-finding problems we observed a marked change in their ability to reason about the cardiovascular system. They started with a system view which was highly anatomic and progressed to one in which system dynamics played a more significant role.

THE ROLE OF COMPUTERS IN TEACHING ABOUT COMPLEXITY

As a general simulation device, computers are well suited for representing complex interactions and describing such behavior with surprising realism. Video games and flight training simulators provide

ample demonstrations of the computer's ability to simulate situations, both literal and imaginary. The video disk offers an almost unlimited opportunity for these kinds of environmental simulations. In addition, mathematical simulation provides a condensed representation of large amounts of knowledge. The description of a particular physiologic, ecologic, electronic, chemical, climatic, or economic system may occupy several chapters in a textbook, but may be represented in a condensed form by only a few differential equations. These equations can be coded to run on the computer. A simulated interface environment can be merged with the condensed knowledge representation to make knowledge accessible in ways that have not been possible before. Computer-simulated laboratories have advantages over traditional laboratories: 1) novices can perform experiments that otherwise would be technically too difficult for them; 2) discovery is much more a part of the learning process; 3) a simulated experiment/laboratory costs much less than the real thing; 4) hazards and potential catastrophies are avioded; 5) simulated labs can be set up in the library or classroom; 6) many more experiments can be performed in the simulated environment than in the traditional laboratory; and 7) ethical problems related to the experimental use of animals are avoided.

Most important, computers allow us to teach abilities that cannot be taught with traditional classroom and laboratory methods. These abilities are the tools for integrating knowledge about components of systems into statements of aggregate system behavior. Integration of knowledge has long been taken as a prerequisite to competence in problem solving and the means for teaching such a perspective has long been sought. The computer is now providing that means. With such a tool,

new instructional techniques are possible. The student may discover the knowledge independently by being given the experimental tools with which to probe the knowledge base. Such practice inculcates not only the knowledge, but also the means by which it may be discovered, i.e., the scientific method.

While traditional "wet" labs teach some things that a computer lab can't, and as such, must remain an important aspect of the training of medical and veterinary students, computer-simulated labs must become as prevalent as the textbook.

In teaching about the cardiovascular system, our goal is to develop the intellectual techniques for using a hierarchy of functions and time scales in a problem-solving scheme--a scheme that allows the identification of a problem in the heart muscle when the initial statement of the symptom is in terms of global system behavior. By using simulations on the computer we have been able to provide students with graphical images at all levels of cardiovascular function. Students can decompose the system and study the pieces individually using simulated laboratory apparatus. They can then re-aggregate the pieces to construct the whole system and examine intact behavior. Such practice is intended to explicitly guide students in developing integrated mental models of system function.

AN INTEGRATED SYSTEMS CURRICULUM

Given that current science curricula are not preparing students to think in ways that make them good problem solvers, and given that tools which allow us to teach integrative thinking can be created, how do we

change the curricula so that college graduates have some knowledge of, and skill in, solving problems in complex systems?

Previously we listed six intellectual abilities for solving problems in complex systems. Learning these are not matters for a single course of study. Rather, an emphasis on knowledge integrations must be added to the whole science and social science curriculum. Students may find a long-sought relevance and applicability of the material in their courses when their instructors can illustrate the parallels in problems, representations, and solutions which exist between disciplines. Before such a goal can be reached there must be a number of complex system simulations, like CVSAD, available for use in various disciplines. The design and development of these teaching tools will require the combined skills of software designers and knowledge experts.

Also, a significant number of faculty members must present the factual content of their courses in a framework of knowledge integration. Frank H.T. Rhodes admonishes that we must "establish structures and incentives that encourage linkage between disciplines and programs....[that we] support and reward the builders of departmental bridges." Under the narrow departmentalization which characterizes our universities, creative, cross-disciplinary teachers are seen as "disloyal and unsound."

We do not expect current faculty members to readily embrace this new responsibility to their students, modification of the curriculum, and restructuring of their thinking. Therefore, as a first step, we propose the training of a new cadre of professionals, knowledge interface designers, to design software and provide training to the faculty on the use of the material. This will be a cooperative process, combining the

expertise of the teacher (subject expert) and designer (software expert). Their goal will be to develop an integrative approach to knowledge.

The educations of these professionals must be liberal, with computer science and mathematical modeling required. In addition, emphasis must be placed on structure and design organization, appropriate representation of design problems, and the limitations of human rationality when working with complex systems. Herbert Simon calls the various elements of an integrative approach to complex systems the "science of the artificial." Since these knowledge designers, in cooperation with the faculty, will be the architects of general curricular changes, it is important that their backgrounds, interests, and abilities be various and cross-disciplinary. Rhodes urges: "Our most gifted scholars should be encouraged to roam widely, to speak not only within but beyond their disciplines, exploring their disciplines' foundations, examining their relationships, and pursuing their implications."

The process of training the new professionals will modify the general curriculum in some ways and set the stage for further modifications. Ernest L. Boyer, president of the Carnegie Foundation for the Advancement of Teaching, puts our educational crisis in its broad, social context. Reflecting in *Phi Delta Kappan*, April 1984, he says: "I wonder how our current push for excellence in education relates to the urgent, deeply disturbing issues our students will confront." After charging the various disciplines with specific tasks, he concludes: "Above all, students should learn to move across the disciplines, to think creatively, and to deal thoughtfully with

consequential issues, understanding that learning must be measured by the wisdom of its application." To give our students a chance to solve the urgent problems facing us, to move toward Boyer's ideals of a creative, thoughtful and wise society, we must teach about the nature of complex systems and ways of thinking integratively to understand those systems. This is only possible by combining an interdisciplinary approach with the new technologies of the information age.